Low emittance tuning

ILC-MAC
21/09/2006

Tuning simulations

Using SAD (K. Kubo)

Initial offsets and tilts:

- Magnets 30 μm, 0.3 mrad
- BPMs 100 μm, 20 mrad

Tuning was applied in three stages:

1. correction of closed orbit distortion (COD);
2. combined correction of closed orbit distortion and dispersion (by steering);
3. correction of coupling (minimizing cross-plane orbit response) using skew quads.

Normalized vertical emittance in nm (target: < 20 nm), averaged over 200 seeds

Lattice	No correction	COD only	COD & dispersion	COD, dispersion & coupling
PPA	879	67.4	4.12	1.74
OTW	101,000	60,400	2,680	1,820
OCS	667	526	106	22.7
BRU	1,630	80.4	2.09	5.05
MCH	4,700	189	6.88	9.27
DAS	10,000	266	22.5	6.12
TESLA	88,100	1,670	29.6	12.6

K. KUBO, ILCDR CERN meeting

BPM and Correctors

Decks of TESLA and OTW include BPMs and correctors but others do not.

BPMs:TESLA and OTW: All BPMs in the decks were used

Others: Put BPMs at Quadrupoles, making total number is about 1000,

Dipole correctors: TESLA and OTW: Select about 135 correctors from correctors.

Others: Put correctors at Quads, making total number is about 135

Skew correctors: TESLA and OTW: Select about 100 correctors from skew correctors.

Others: Put correctors at Sextupoles, total number is about 100.

Number of correctors and BPMs

	PPA 2.8 km, 5.0 GeV, pi	OTW 3.2 km, 5.0 GeV, TME	OCS 6.1 km, 5.1 GeV, TME	BRU 6.3 km, 3.7 GeV, FODO	MCH 15.9 km, 5.0 GeV, FODO	DAS 17.0 km, 5.0 GeV, pi	TESLA 17.0 km, 5.0 GeV, TME
Number of dipole correctors, x/y	128/128	120/120	127/127	131/131	99/99	135/135	135/135
Number of skew quad correctors	56	92	96	101	101	56	101
Number of BPMs	768	240	760	850	1038	808	946

Three consecutive corrections [3].

- COD correction: using steering magnets, minimize
  $\sum_{\text{BPM}} x^2$ and $\sum_{\text{BPM}} y^2$,

  where is horizontal (vertical) BPM reading.

- Vertical COD-dispersion correction: using steering magnets, minimize
  $\sum_{\text{BPM}} y^2 + r^2 \sum_{\text{BPM}} \eta_y^2$,

  where η_y is the measured vertical dispersion. r is the weight constant which was set to be 0.05.

- Coupling correction: using skew quads, minimize
  $$C_{xy} \equiv \sqrt{\sum_{\text{H-steers}} \left(\sum_{\text{BPM}} \Delta y^2 \Big/ \sum_{\text{BPM}} \Delta x^2 \right) \Big/ N_{\text{steer}}}$$
  where $\Delta x(\Delta y)$ is the horizontal (vertical) position change at a BPM due to excitation of a horizontal steering magnet. Two horizontal steering magnets were used in the simulations, (N_{steer}=2).

- BPMs and dipole correctors were placed at every quadrupole magnet in the lattice, and skew quadrupoles at every sextupole.
- Alignment errors are assumed to be randomly Gaussian distributed within 2 sigma.

Table 1 Alignment Tolerances

	Δx (μm)	Δy (μm)	ΔΨ (mrad)
Quadrupole	30	30	0.3
Sextupole	30	30	0.3
BPM	100	100	20

Coupling correction

- Minimisation of cross-plane response Matrices using skew-quadrupoles.
- The coupled motion is excited by horizontal kickers, and the vertical motion on a set of BPMs analysed to determine the relative amount of coupling.
- The choice of horizontal kickers affects the coupling signal seen.
- 4 horizontal kickers were used: 2 were spaced with a phase difference of $\pi/2$, the other 2 with a phase sum of $\pi/2$.

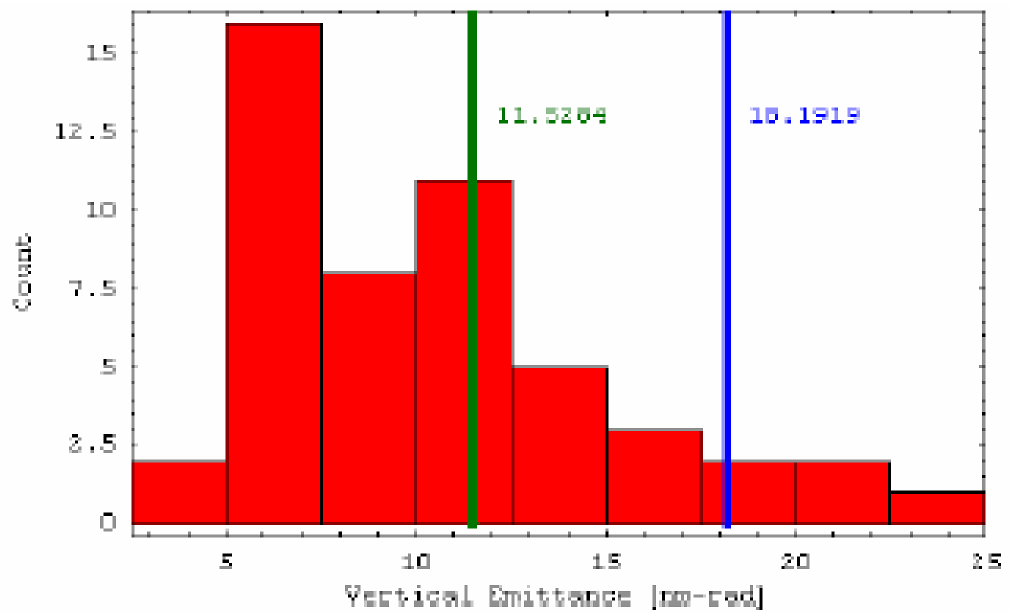
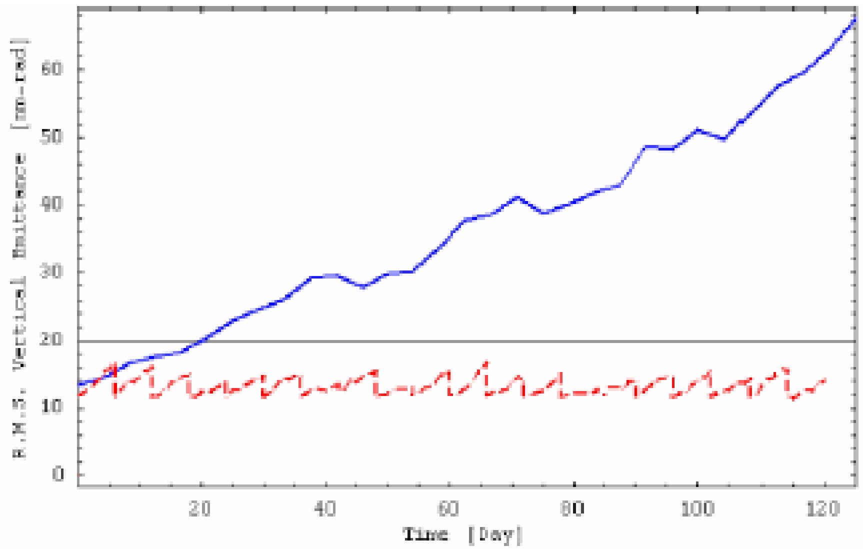


Figure 3 Tuned vertical emittance values, showing the r.m.s (green) and 90% confidence limits (blue).

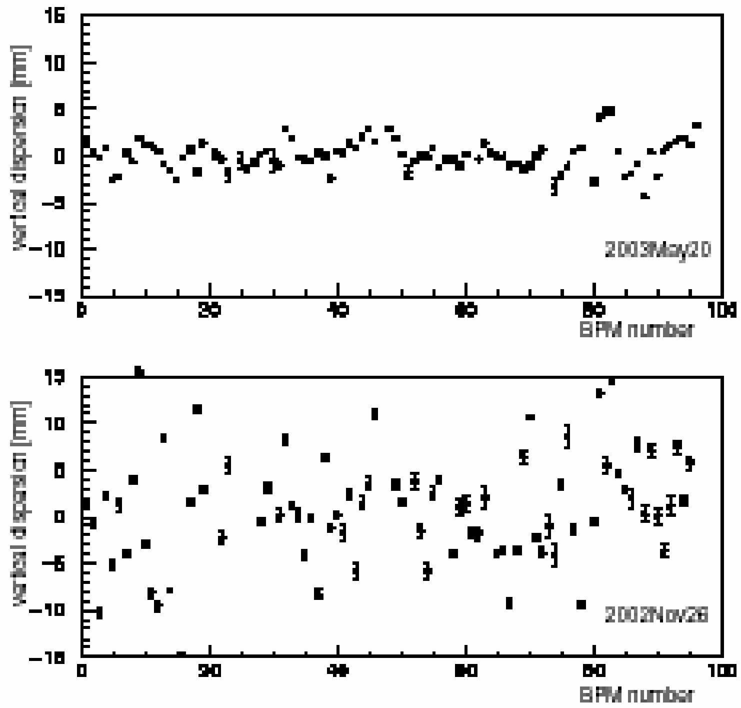
Ground motion

- The ground is assumed to have an A coefficient of 100£gm/10m/Year.
- The simulation is initially seeded with the alignment tolerances given in Table 1 the ring was then allowed to move under the influence of ATL motion.
- Emittance tuning every 6 days is sufficient to maintain the vertical emittance below the target of 20nm-rad over the 4 months period.



ATF - Low emittance tuning

- Vertical dispersion after COD and dispersion correction.
- Measured before and after improvement of BPMs readout circuits and other beam based optics updates.

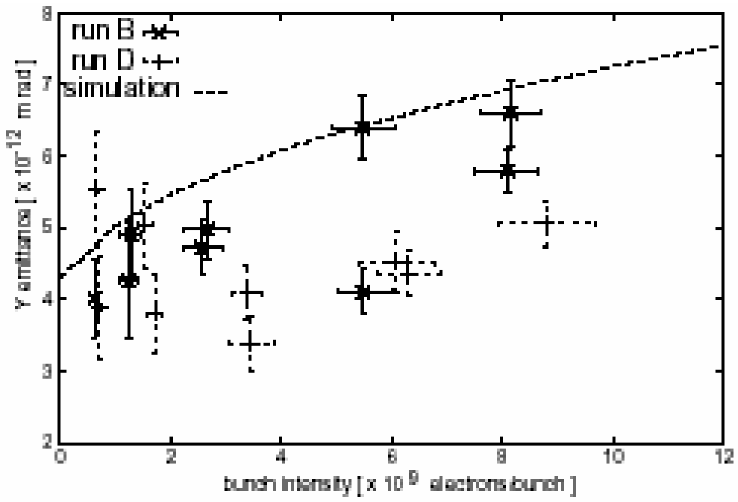


Y. Honda et al, “Achievement of Ultralow Emittance Beam in the Accelerator Test Facility Damping Ring,” Phys. Rev. Lett. 92, 054802-1(2004).

ATF - Low emittance tuning

Vertical dispersion and coupling correction are iterated

4pm



Vertical emittance measured with laser wire in the ring vs. bunch intensity

ATF - Low emittance tuning

Table 1: Results of low-emittance tuning in the ATF.

Date	BPM Resolution	BBA Used	Residual Dispersion	Vertical Emittance
11/02	20 μm	No	5.8 mm	> 10.5 pm
3/03	5 μm	No	4.2 mm	6 – 10 pm
5/03	5 μm	Yes	1.7 mm	3.5 – 5 pm

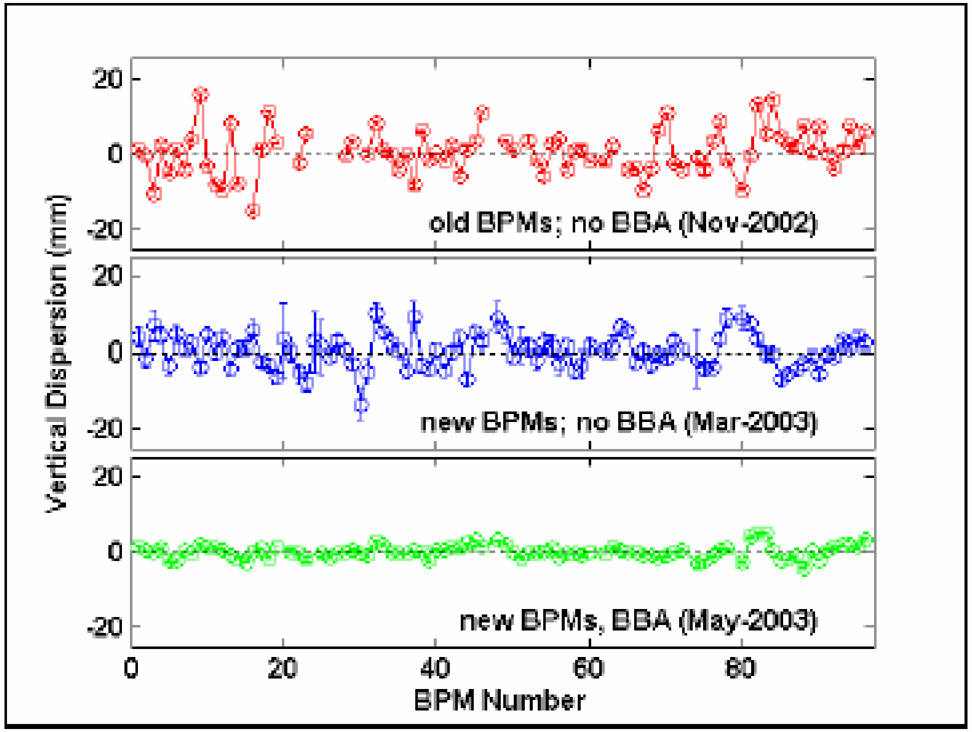


Figure 5: Residual vertical dispersion in the ATF after low-emittance tuning.

M.D. Woodley et al.
MOOCH01-EPAC04

I.L.C. Damping Rings RF System

HIGH α_c option

R. Boni – INFN-LNF

D.R. MAIN RF PARAMETERS

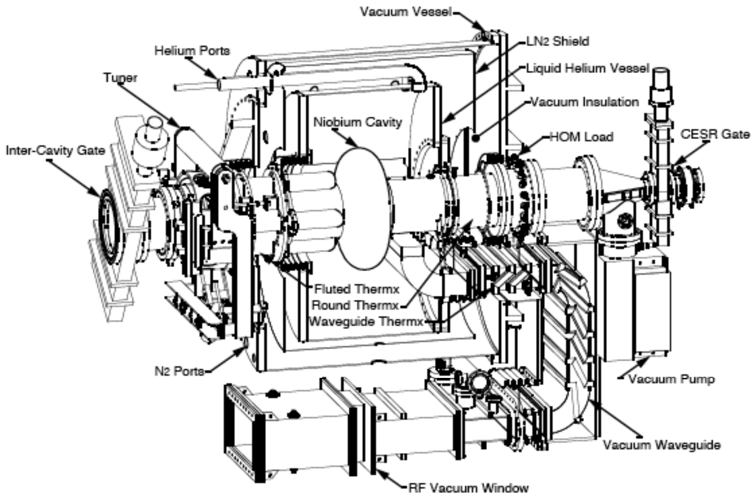
Damping rings parameters		
	e- RING	e+ RINGS
Energy (GeV)	5	5
Number of bunches per train	2767	1384
Number of particles per bunch	2×10^{10}	2×10^{10}
Average current (amps)	0.4	0.2
Energy loss per turn (MeV)	8.7	8.7
Beam power (MW)	3.5	1.75
Bunch current (mA)	0.14	0.14
Total RF voltage (MV)	46.6	46.6
Circumference (km)	6.695	6.695

BEAM POWER

- → **3.5 MW** → **ELECTRON RING**
- → **1.75 MW + 1.75 MW** → **POSITRON RINGS**

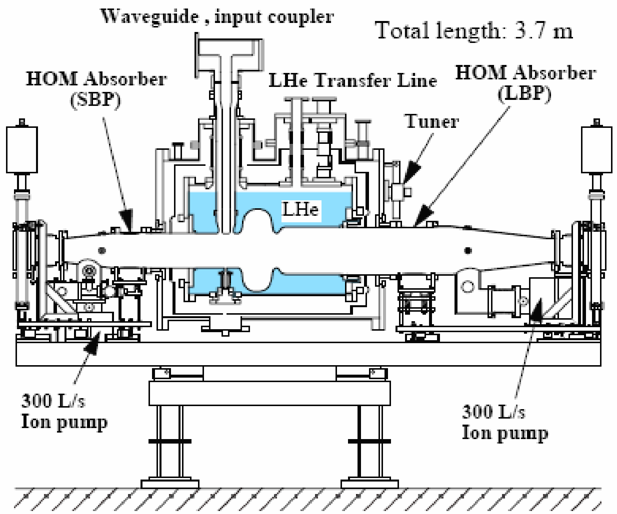
RF VOLTAGE → **46.6 MV in e- and e+ RINGS**

HIGH RF VOLTAGE → SUPERCONDUCTIVE RF



[CESR CRYO-MODULE]

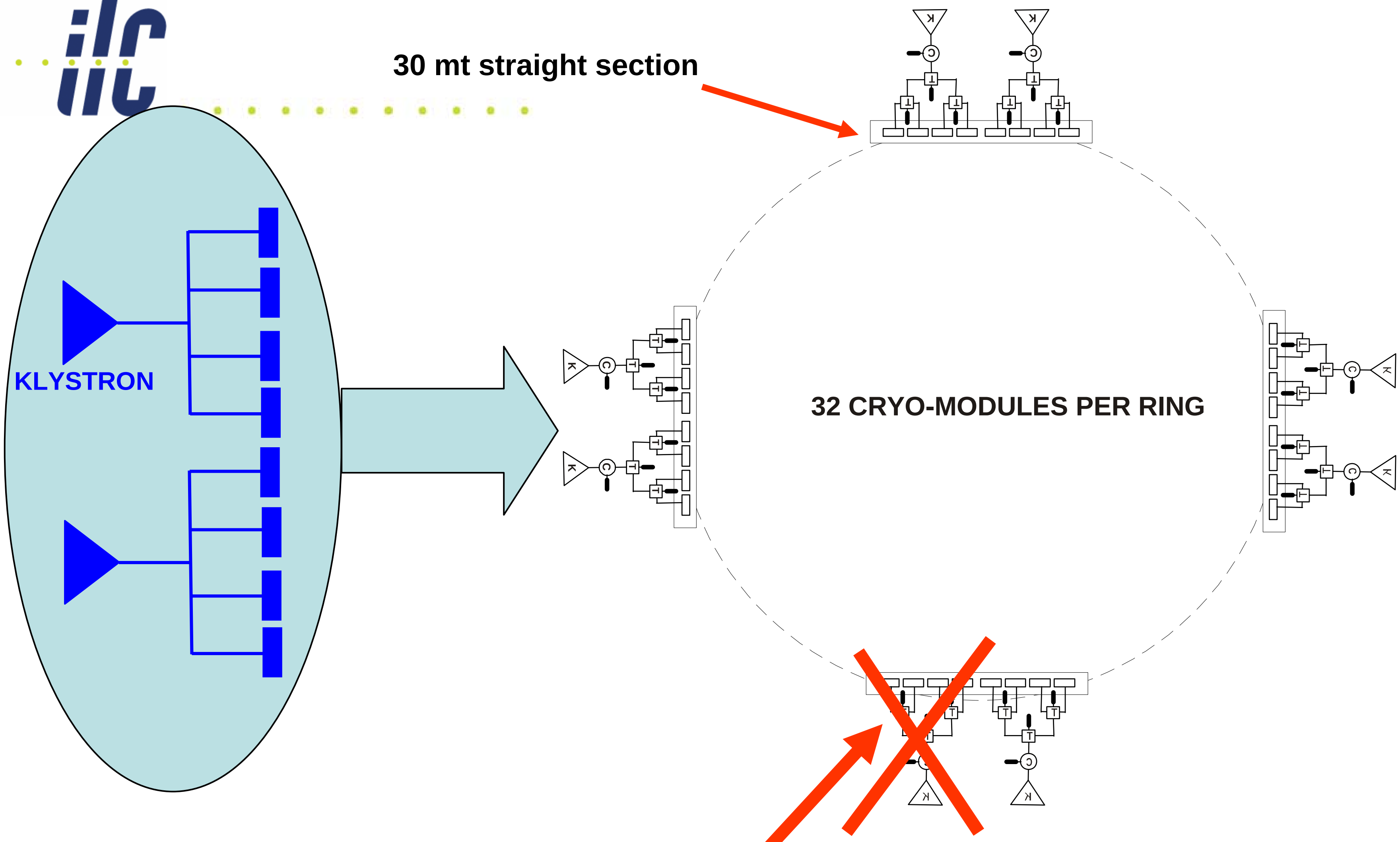
or ....



[KEK-B CRYO-MODULE]

Length ~ 3.5 m

Transverse Diameter ~ 1.5 m



The system is powerful enough to meet the specifications in case of one RF station fault

32 CRYO-MODULES per RING
8 RF STATIONS per RING

Estimated 650 MHz SC cavity parameters (scaled from 500 MHz model)

	Electron ring		2 x Positron ring	
Frequency [MHz]	650		650	
Active cavity length [m]	0.23		0.23	
R/Q [Ω]	89		89	
Operating temperature [K]	4.5		4.5	
Standby losses at 4.5 K [W]	30		30	
Number of cryo-modules in operation per ring	32	28 (1 station OFF)	32	28 (1 station OFF)
Accelerating gradient [MV/m]	6.33	7.2	6.33	7.2
Accelerating voltage [MV]	1.45	1.66	1.45	1.66
Qo ($x10^9$) at operating gradient	1	0.9	1	0.9
Cryo-RF-losses per cavity [W]	23.6	34.4	23.6	34.4
Total cryo-losses [W] per ring	1716	1803	1708	1803
Beam power per cavity [kW]	109	125	53	61
Qext [$x10^3$]	215	248	445	507
Number of klystrons per ring	8	7	8	7
Klystron output power [kW]	436	500	212	243

32 CRYO-MODULES

input power → 53 - - - 125 kW

acc. gradient → 6.3 - - - 7.2 MV/m

per SC cavity

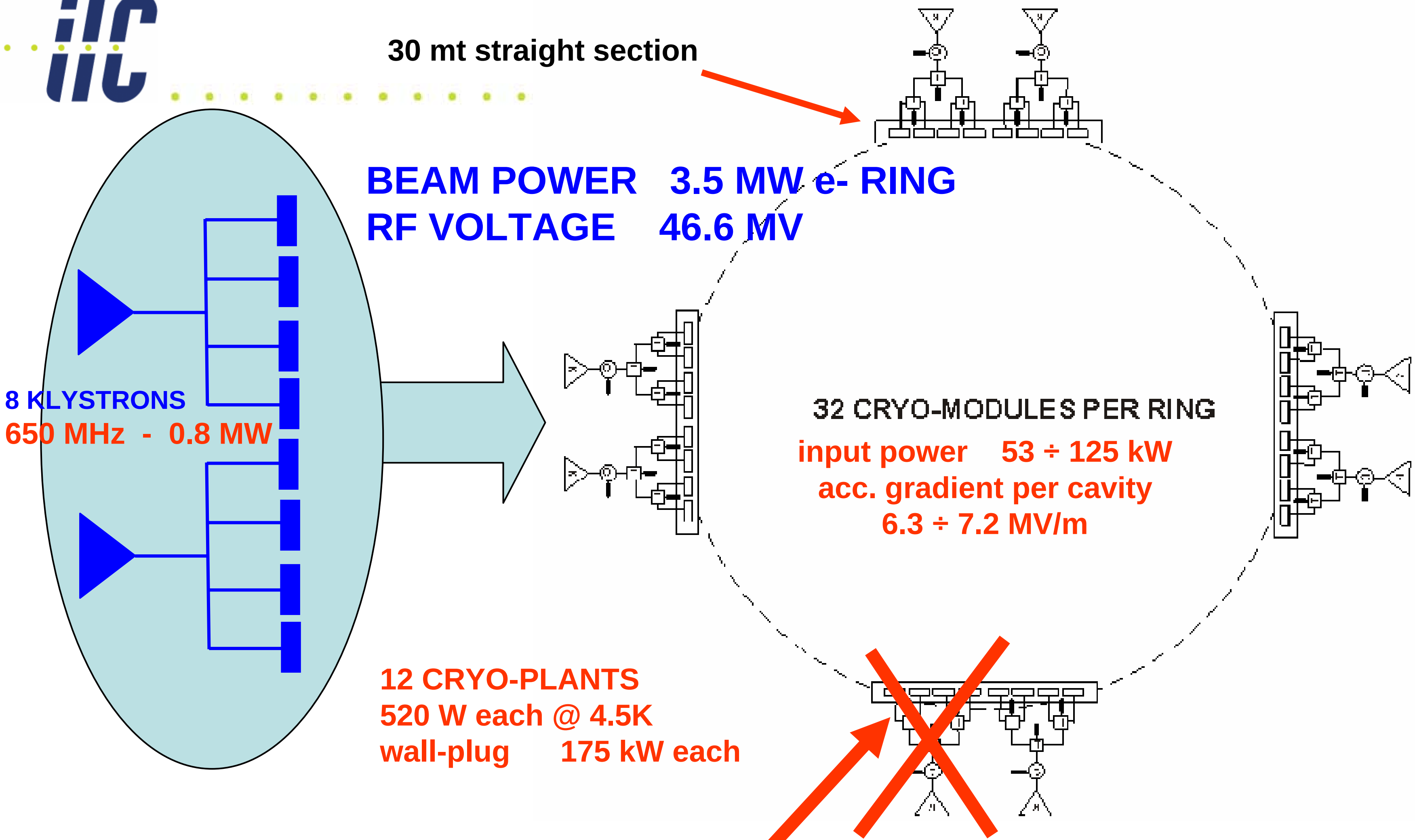
8 KLYSTRONS

650 MHz - 0.5 MW

12 CRYO-PLANTS

520 W each @ 4.5K

wall-plug → 175 kW each



The system is powerful enough to meet the specifications in case of one RF station fault

RF units

The modification of the frequency from 500 to 650 MHz requires to re-design the cryo-module. In fact, the cavity shape must be scaled from 500 MHz; the input coupler and the HOM dampers must be re-designed too. The input coupler is the most critical element in a new 650 MHz structure, mainly because the power handling capability, that is about 260 kW-CW in the 500 MHz system, must be of comparable level in the new design. Scaling the HOM dampers, wrapped around the beam pipe warm sides, does not appear a hard work. Finally, the cryostat must be considerably renewed, especially the cavity LHe tank, for the smaller cavity dimensions and the “warm-to-cold transitions”. Anyhow, the large number of needed cryo-modules justifies the effort of developing a new unit.

RF sources

The RF stations will consist of the CW 650 MHz klystron supplied by its CW Power Supply. New RF power sources are necessary. Klystrons of power and frequency close to the needed ones exist on the market and can be modified by the manufacturer, with a moderate R&D effort. The RF industry [1] is available to develop the new power source. HV power supplies for this type of klystrons are in operation at DESY. Ferrite circulators for the klystron protection can be developed too. Products with similar specifications are being operated in other laboratories.

Cryo-modules

In the light of the information and discussions with other users, we deem that a realistic cost of each fully equipped 650 MHz cryo-module would be about …M€ and that the R&D cost of the new module should be considered as an extra unit (1/96)

RF Stations

Information from the industry, gives a cost of about …k€ per/klystron. This price includes the focusing coils. In this case too, the R&D, necessary to develop a new unit, is estimated like the cost of an additional item (1/24).